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13. ABSTRACT *(Maximum 200 Words)*

This project is to facilitate research in digital mammography and related technologies, in particular computer-aided diagnosis and image processing. A major limitation to the rapid development and subsequent clinical implementation of these technologies is the lack of a standardized set of mammograms to be used in development and evaluation. We are developing a method to produce simulated mammograms. The method relies on a model of image formation that takes into account the absorption of x-rays in the phosphor, subsequent conversion to light and the scattering of the light before escaping the phosphor. The model also takes into account the finite thickness of the phosphor, the divergence of the x-ray beam, scattered radiation, and noise due to film granularity and from the film digitizer. Almost all the components of the model are completed and computer code is being written. The model requires as input high fidelity images of breast tissue and of breast lesions. We are now testing the model using x-ray phantoms. We are comparing simulated images created based on a high quality film radiograph to an image acquired using a mammographic screen-film system.

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Table of Contents

4. INTRODUCTION

This project is to facilitate research in digital mammography and related technologies, in particular computer-aided diagnosis and image processing. A major limitation to the rapid development and subsequent clinical implementation of these technologies is the lack of a standardized set of mammograms to be used in development and evaluation. We are developing a method to produce computer-simulated mammograms. The approach is to model the creation of the mammogram on the computer -- all steps from x rays exiting the breast to the image being displayed on a light box. This model, which we have developed previously, will be combined with accurate information of the appearance of normal breast anatomy and of benign and malignant breast lesions. These will be obtained from high quality images of mastectomy samples and biopsy specimens. We believe that this technique can produce simulated mammograms that appear to be actual mammograms. We will test this hypothesis by performing quantitative comparisons of simulated and real mammograms. We will also perform an observer study where radiologists choose the real mammogram from a pair of real and simulated mammograms shown side by side.

5. BODY OF REPORT

5.1 Tasks

There are four tasks in the Statement of Work, which are listed below.

1. To obtain radiographs of mastectomy and tissue specimens

(a) radiograph 100 different mastectomy breast tissues at 2.0 times geometric magnification recording image on direct film (without intensifying screen) at five different orientations

(b) radiograph 240 different tissue specimens at 4.0 times geometric magnification recording images on direct film (without intensifying screen) at five different orientations

(c) segment lesions from specimen radiographs and measure their size, contrast, and shape metrics

2. To develop further a computer model of image formation

(a) modify previously developed model for point source versus parallel beam

(b) measure and model detector noise for film digitizer and screen-film system

(c) measure scatter as a function of position in the image

(d) measure beam intensity as a function of position in the image

3. To produce simulated mammograms

(a) produce simulated mammograms with and without lesions

(b) make preliminary comparison to actual mammograms

(c) make adjustments to model, if necessary

4. To evaluate simulated images

(a) collect real mammograms: normals and those with lesions

(b) compare real and simulated mammograms based on quantitative measurements

(c) conduct pilot observer study

(d) conduct observer study comparing ROIs from real and simulated mammograms

5.1.1 Obtain radiographs of tissue specimens and mastectomies

We have purchased a Faxitron, which would allow us to make high-resolution images of the samples. This prevented us from radiographing breast tissue last year. However, we still have not collected tissue images because the research technician that was going to be hired to work on the project back down at the last minute. We have hired a new technician, but he will not start until the middle of September. At that time, we will coordinate our efforts with those of the new chief of breast surgery and start collecting tissue samples.

5.1.2 Further development of computer simulation method

The theoretical basis for the model has been developed previously by the PI, but with a number of simplifying assumptions [1]. For this project, we need to check these assumptions and include other relevant factors particular to our application. In addition, we need to cover the theory into a computer program that can produce a simulated image. Our efforts in these areas are described below.

5.1.2.a Modify model from parallel beam of x rays to x rays from a point source.

Completed. See last years report.

5.1.2.b Model detector noise for film digitizer and screen-film system.

Completed. See last years report.

5.1.2.c Measure scatter as a function of position in the image

This will be done using mastectomy samples, which we will do next year.

5.1.2.d Measure beam intensity as a function of position in the image

We are in the process of producing "uniform" air exposure on film from a standard mammography x-ray unit and from our Faxitron unit. These films will be digitized to determine the x-ray intensity distribution incident on the detector and a correction will be built into the model via a look-up table based on position in the image with respect to the central axis of the x-ray beam..

5.1.3 Produce simulated mammogram

Production of simulated mammograms be done after tissue samples have been collected. Currently, we are testing the technique using phantoms. That is, we are making images of the phantoms as we would the breast tissue – on Kodak XV film (non-screen system) using four times geometric magnification that will produce a high fidelity image. The images are taken on the XV film will be digitized at 50-micron pixel resolution. The resulting image will be put through our simulation model to produce an image with the same exposure as used for the standard mammography system – a Kodak Min-R 2000 system. We will use published MTF and noise power data in our model [2], along with our measure characteristic curve data for the Min-R 2000 system. The characteristic curve data will also be compared to the published data [2] to correct the magnitude of the noise power spectrum, since the magnitude of the noise power spectrum is proportional to the square of the slope of the characteristic curve.

To compare the simulated image to the screen-film image, we will digitize the screen-film image at 50 microns and construct a 50-micron resolution simulated image. We will then subtract the two images. If the images are identical, the result will be zero. However, the noise in the image is a statistical process and cannot be modeled exactly (unlike deterministic processes, such image blurring). Therefore the subtraction of two images should yield a slow changing noise image, without any high-frequency structure. There will be some variation because the noise is related to the film density. There will also be some misalignment due to sampling and rotation of one image with respect to the other. These can be separated visually from mismatching due to the shortcomings of the simulation model. It is unlikely that we will be that successful and we will examine how to modify our model to improve the quality of the simulated images.

We will use three different phantoms: the ACR accreditation phantom, a contrast detail

phantom and the International Digital Mammography Development Group (IDMDG) QC phantom, which will be the QC phantom used in the ACRIN-sponsored Digital Mammography Screening Trial. The contrast-detail phantom is composed of 15 mm of Lucite with circular posts (i.e., cylinders) of different heights and diameters milled into the surface. There are 9 different heights ranging from 0.062 mm to 1.00 mm covering a range of low contrasts; and there are 10 different diameters ranging from 0.312 mm to 7.071 mm. The IDMDG phantom is a large block of Lucite with a mercury-intensified film containing a number of test objects. There are bar patterns and a straight edge for resolution, stepwedges for contrast, uniform areas for noise evaluation. In addition there is a series of stars (5-pointed objects) ranging in size from approximately 50 microns up to 500 microns. These stars should be an excellent test for the simulation program.

5.1.4 Evaluation of simulated mammograms

The observer study is planned for year three. It is dependent on completion of 5.1.3.

5.2 Recommendations in relation to the Statement of Work

We are making more extensive use of phantom images to test the validity of our simulation program than we originally proposed. This approach will allow for more rigorous comparisons of simulated and actual images, permitting more in-depth study of how to improve our simulation program.

6. KEY RESEARCH ACCOMPLISHMENTS

- Computer model is being refined.
- Testing of the simulation technique using phantom images is underway.

7. REPORTABLE OUTCOMES

None so far.

8. CONCLUSIONS

Progress has been slow this year because the research technician that was going to work on this project declined our offer of employment at the last minute. After a long search, a new research technician has been hired and will begin on 9/17/01. We are currently conducting a comparison of simulated images of x-ray phantoms to actual images of the phantoms. This will allow use to analyze the performance of our simulation model and to improve it where necessary.

9. REFERENCES

1. R M Nishikawa and M J Yaffe, "Model of the spatial frequency-dependent detective quantum efficiency of phosphor screens," Medical Physics **17 (5),** 894-904, 1990.

2. Bunch PC: Advances in high-speed mammographic image quality. Proc SPIE **3659**: 120-130, 1999.